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INTARGRAF: Artificial Intelligence for Geometric Modeling and Computer Graphics TIN2006-13615

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Abstract

This research project focuses on the application of Artificial Intelligence (AI) techniques to the fields of Geometric Modeling and Computer Graphics. Our goals are the determination, analysis, implementation and evaluation of different AI techniques to solve several problems in both fields. Our aim is not only determining the AI tools best suited for each problem considered, but also the development of new AI-based schemes for those cases in which current paradigms do not provide satisfactory solutions.
Keywords: Artificial Intelligence, Computer Graphics, Geometric Modeling, Behavioral Animation, Surface Reconstruction, Functional Networks, Virtual Agents.

1 Project goals

INTARGRAF is an A-Type[1] research project aimed at applying Artificial Intelligence (AI onwards) paradigms to Geometric Modeling and Computer Graphics. Our primary goals are the determination, analysis, implementation and evaluation of AI techniques to solve challenging problems in both fields. In particular, two major problems (deriverables) are addressed:
(DV1) the *realistic behavioral simulation of autonomous intelligent virtual agents evolving on a virtual 3D world*: these virtual agents, graphically represented by synthetic actors within a 3D digital world, must be **intelligent** (i.e. they should be able to: reproduce human behavior in a realistic way, adapt to environmental changes, interact with other agents and objects, learn from experience, etc.). Further, agents' actions and decisions must be fully **autonomous** (with minimal user's input and neither scripts nor human intervention once simulation is triggered).
(DV2) *solving some problems in the realm of geometric modeling with a great potential in industrial settings and a strong mathematical and computational content.* Examples of these problems are: surface reconstruction (determination of a surface from a cloud of unorganized 3D data points according to some prescribed functional criteria) and sectioning (intersection of mechanical parts comprised of hundreds/thousands of NURBS and implicit surfaces).

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[1]Young researchers achieving high-quality research on a hot topic and leading small but growing teams with the potential to become medium-sized groups in a short-term.

1.1 Project planning and schedule

Project activities and schedule are depicted in Fig. 1. Note that activities 1,3,5,7,9 and 10 are parts of DV1, whilst activities 2,4,6 and 8 are associated with DV2. Activity 0 concerns the general coordination of all research tasks so it is carried out throughout the project. Note also that some activities are still in progress, as the project will actually finish in Sept. 2009.

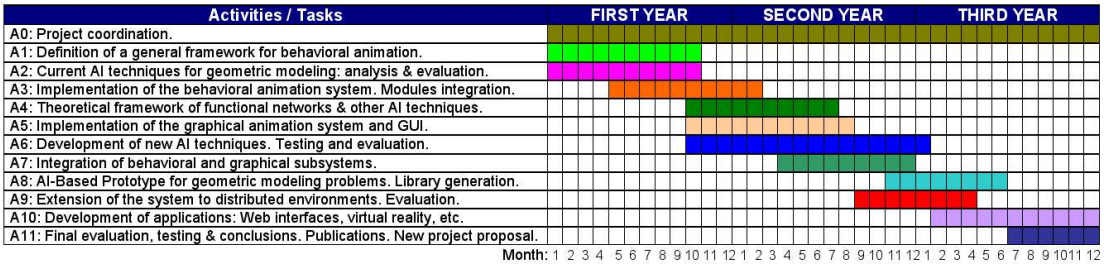

Figure 1: Gantt chart of project activities.

2 Project attainments

Next paragraphs describe the main scientific and technological breakthroughs of this project.

2.1 DV1: Behavioral animation of virtual actors

Our main contribution in this topic is the theoretical and computational development of a general framework for behavioral animation of virtual actors. Its powerful features (including platform-independence, modularity, extensibility, parallelization, adaptability and others) help to simulate human behavior in a very realistic way. The system handles sophisticated processes such as goal selection, action planning and execution, procrastination, rejection acceptance, denial, reliability on trust, self-confidence, inclusion of personality, reasoning, uncertainty, motivational issues, etc. As a result, virtual agents are able to evolve autonomously within virtual 3D worlds, taking decisions (either individual or collective) by themselves and performing actions to achieve their goals. Our approach has a very flexible architecture; different tasks can readily be associated with specific layers comprised in its turn of task-oriented modules:

(a) the *behavioral layer*: implemented in *C++* and *Amzi!Prolog*, it encompasses agents' emotions, feelings, thoughts, needs and beliefs in order to perform many cognitive tasks (memory, learning, deduction, etc.). All these processes are handled by different AI modules. A clustering method based on K-means scheme has been applied on both a SOM and a auto-associative multilayer back-propagation network with unsupervised learning (implemented in *Matlab*) for memory simulation purposes, rule-based expert systems and a logic programming module (implemented in *Prolog*) are used for deduction, probabilistic expert systems (in *C*) and a fuzzy logic module (in *Matlab*) simulate the uncertainty. We also developed functional networks schemes (in *Mathematica*) for agent internal states management and action selection.

(b) the *physical layer*: it comprises agents' physical routines for perception and motion. The perception subsystem (in *C++*) contains routines for environment exploration (in *C*), geometry

recognition and information acquisition (through genetic algorithms in *Matlab*) and a module for collision-avoidance (a modification of the A^* algorithm, developed in this project). The motion subsystem uses Internet available data from mocaps (motion capture systems) inputted to animation software via an XML-based protocol original of this project.

(c) the *graphical layer*: it accounts for rendering and animation of the 3D environment and its physical elements, their geometry, location, motion and animation and possible interaction among all objects and agents. Graphical tasks are performed in *Open GL* with *GLUT* (Open GL Utility Toolkit) for the higher-level functions (windowing, menus, or input) along with *Microsoft Visual C++* as the programming environment for best performance. We point out the excellent integration of *Open GL* with previous *C++*-grounded layers.

We accomplished the overall system verification and validation through Petri nets (in *Mathematica*) and are currently working on generating intelligent interfaces through semantic web services (with a *DAML-S* translator, a knowledge database and an *OWL* reasoner built in *Prolog*). We are also working on the parallelization of graphical and AI processes, their integration into distributed systems under a client-server architecture and publication of results.

2.2 DV2: Artificial Intelligence for Geometric Modeling

We have developed original geometric modeling methods by using *functional networks* (FN), a neural networks generalization where weights are replaced by functions. This allows us to accurately describe the functional structure of the given problem. For instance, we addressed the Bspline surface reconstruction problem by combining FN with the hybrid *genetic algorithms-least squares* scheme (the former being used for surface parameterization, the last for data point fitting). We solved the resulting nonlinear systems by the *Singular Value Decomposition* (SVD) method, obtaining very good fitting results. We are now applying heuristic approaches, such as *Particle Swarm Optimization*, which turn out to yield promising results. Recently, we succeeded in solving the problem for NURBS by means of our RBS functional networks (developed in this project) with PSO parametric learning to determine all at once knot vectors, control points and weights of the fitting surface and parametric values of given data points. We plan to apply *Swarm Intelligence* (SI) techniques as part of a new project proposal.

We also addresed the sectioning issue by using an original hybrid *geometric-differential approach*, leading to initial value problems in systems of explicit low-order ordinary differential equations (ODEs), which can be efficiently integrated by standard numerical methods. So far, we successfully applied our method to the *intersection of parametric and/or implicit surfaces* (all cases) and *tool-path generation in numerically-controlled machining*, a very important issue in industry. Such trajectories include parallel, geodesic, silhouette, projection and section curves. Our procedure is very general and has received significant attention from international groups that started to apply it to their own problems. Extension of our procedures to T-NURBS and NURCCS are goals of the upcoming proposal for project's renewal.

3 Result indicators

Previous section summarized the scientific and technological results of this project. This section focuses on the evaluation results (publications, training, collaborations, etc). We remark that the project is not finished yet; further ongoing results are expected for the next few months.

3.1 Publications

Table 1 reports the list of international publications of the project in terms of published/accepted and submitted papers. The corresponding entries are listed in the References section.

Table 1: Summing up of project's international publications (as of January 2009)

Publication:	*Published/Accepted*	*Submitted*
Journals	[2],[5],[9],[18],[20],[21],[23]	[10],[14],[28],[29],[30],[35]
LNCS	[3],[7],[8],[11],[13],[32],[33],[34]	
IEEE	[4],[12],[26],[27],[31],[37]	[15]
Book Chapters	[1],[6],[19],[24],[38]	
Edited Books	[16],[36]	
Special Issues	[17],[22]	[25]

3.2 Learning and training activities

Since 2005, the leader of this project is also the Ph.D. coordinator at his department. As such, he managed two postgraduate programs, both awarded with the **"Mención de Calidad" (MC)** of the Spanish Ministry of Science & Innovation (formerly, of Education & Science):

• **(P1)** a *Ph.D. program (ruled by the R.D. 1998)* with the **MC** for the period 2005-2011. As a result of the project, one Ph.D. thesis (co-supervised by project's leader) was defended:

> Akemi Gálvez: *"Computational Methods for Surface Interrogation and Applications"*. **Ph.D. thesis**, Dept. of Applied Mathematics and Computational Sciences, University of Cantabria ("Summa Cum Laude", dissertation date: March 7th 2007).

After her dissertation, Dr. A. Gálvez was awarded with a grant of *FLTQ-Fundación Leonardo Torres Quevedo* and then a highly-competitive **post-doc grant** from the University of Cantabria. Currently, she holds a position as teaching assistant. Two more Ph.D. thesis on the project (Gonzalo Echevarría, Marta Collantes) are currently being carried out under this program.

• **(P2)** a *POP program (R.D. 2005)*: the former program was adapted to new regulations in 2008. The resulting studies (with Bologna's Master+Ph.D. structure) also got the **MC** in 2008. The program offers students a major on Computer Graphics and Geometric Modeling with emphasis on project's topics. A new Ph.D. student joined the project in 2008 (Andreina Avila) and another one is scheduled for the next academic year (Luis Cabellos, from CSIC). Finally, Prof. Francisco Luengo (Head of the Informatics department of University of Zulia, Venezuela, and author's former Ph.D. student) joined our group in 2007.

In short, **the group increased from the initial four members (3.5 EDP) to six members (5.5 EDP) plus four Ph.D. students and five Master students**. The research group also supports **a specialized Master program and a MC-awarded Ph.D. program in project's topics**.

3.3 Dissemination activities

Table 2: International conferences supported by the project

Conference:	*Location*	Date	# papers submitted/accepted	Publisher
CGGM'06	Reading (England)	May 2006	43/18	LNCS (vol. 3992)
TSCG'06	Glasgow (Scotland)	May 2006	46/13	LNCS (vol. 3980)
ICMS'06	Castro Urdiales (Spain)	Sept. 2006	89/45	LNCS (vol. 4151)
CGGM'07	Beijing (China)	May 2007	116/20	LNCS (vol. 4488)
TSCG'07	Kuala Lumpur (Malaysia)	Aug. 2007	46/24	LNCS (vol. 4706)
CGGM'08	Krakow (Poland)	June 2008	43/16	LNCS (vol. 5102)
TSCG'08	Perugia (Italy)	July 2008	22/10	IEEE CS Press
VRSAL'08	Perugia (Italy)	July 2008	21/10	LNCS (vol. 5073)
ICCIT'08	Busan (Korea)	Nov. 2008	1479/396	IEEE CS Press
CGGM'09	Louisiana (USA)	May 2009	*in progress*	LNCS (TBD)
CGVR'09	Yongin (Korea)	June 2009	*in progress*	IEEE CS Press
ICCIT'09	Seoul (Korea)	Nov. 2009	*in progress*	IEEE CS Press

Regarding project dissemination activities, they can be grouped into the following categories:
1. Organization of 12 international conferences and/or workshops (see Table 2 for details):

- *Int'l Workshop on Computer Graphics and Geometric Modeling, CGGM*: annual event currently in its eighth edition (see `http://personales.unican.es/iglesias/CGGM2009/`).
- *Technical Session on Computer Graphics, TSCG*: annual event celebrated last time in 2008 (see `http://personales.unican.es/iglesias/TSCG2008/`).
- *Virtual Reality in Science and Learning, VRSAL*: annual event celebrated last time in 2008 (see `http://personales.unican.es/iglesias/TSCG2008/`). For 2009, TSCG and VRSAL merged into CGVR (`http://ogervasi.unipg.it/CGVR`).
- *II International Conference on Mathematical Software, ICMS'2006* (`www.icms2006.unican.es/`): a satellite event of ICM'2006, International Congress of Mathematicians, world's largest conference on Mathematics, held every four years, last time in Spain in 2006.
- *Int'l Conf. on Convergence Information Technology, ICCIT*: annual event held in 2008 in Busan (Korea) (`http://nms.dongguk.ac.kr/iccit08/`).

2. Jointly with KETpic team (see Section 3.4 for details), we organized 2 scientific meetings in Japan, at Kisarazu (Sept. 2007) and Shinjuku (Aug. 2008).

3. In June 2008 a free-access exhibition forum (the "Open-door day on Computer Graphics" event) reporting our research was held at the Faculty of Sciences of our university. It received about 500 attendees with coverage by the largest regional newspapers "El Diario Montañés", national press agencies (Europa Press) and web portals (Universia). It was also broadcasted by regional TV channel "CantabriaTV". A similar initiative is scheduled for March 2009.

In short, the project has allowed us to **organize 12 international conferences and workshops, 2 scientific meetings and 2 open cultural activities**.

3.4 Scientific collaborations with other groups

We have established relationships with different national and international groups. As a result, joint projects[2], publications and stays have been carried out.

International Groups

- (⋆⋆) *KETpic Team: Toho University (Funabashi, Japan), Kisarazu National College of Technology (Kisarazu, Japan), Kogakuin University (Tokyo, Japan).* In 2007 we joined KETpic consortium and started a common project supported by the Japan Society for the Promotion of Science (Ref. KAKENHI 20500818). We organized two scientific meetings in Japan at Kisarazu (Sept. 2007) and Shinjuku (Aug. 2008) on KETpic software and published common papers.
- (⋆⋆) *Laboratory of Artificial Intelligence & Computer Graphics, University of Zulia (Venezuela).* The laboratory chair is also member of our research group. We publish common papers.
- *Research Center on Voronoi Diagrams, Hanyang University (Korea).* We co-organized TSCG annual workshop series with its Director, Prof. Deok-Soo Kim for the period 2004-08.
- *Dept. of Mathematics & Comp. Science, University of Perugia (Italy).* We collaborate with the group of Prof. Osvaldo Gervasi in conference organization (ICCSA, VRSAL, CGVR).
- *Advanced Institute of Convergence & IT, Dongguk University (Korea).* We collaborate with its Director, Prof. Il Seok-Ko in conference organization (ICCIT'08) and editorial board membership of some international journals (IJCIT, IJDCTA).

National Groups

- (⋆⋆) *SIG Rural, Polígono del Trascueto - CEMCAM, Camargo, Spain.* Spanish company aimed at providing technological solutions and services along with consultancy, technical support and training in Information Technology, including database services, networking, multimedia and virtual reality. We developed a common project for Santander City Council in 2008.
- (⋆⋆) *Fundación Leonardo Torres Quevedo, FLTQ.* One of our group members, Prof. P. Corcuera, has strong ties with FLTQ through several research projects. This relationship solidified into a grant for Dr. A. Gálvez (also group member), allowing us to keep this valuable member in our team (see Sect. 3.2). FLTQ also supported the organization of ICMS conference (see Sect. 3.3).

3.5 Project management

In general, the main goals of the project have been successfully attained. The project has been carried out on both time and budget and research group has increased in people, resources and results. They clearly show that project development and management are satisfactory and encouraged us to propose the project renewal. We have no other significant issues to mention.

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